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A search for waves in Saturn's stratosphere with TEXES/IRTF

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Abstract

We report on the mapping of Saturn's stratospheric temperature in April 2015 using the Texas Echelon cross Echelle Spectrograph (TEXES, [1]) mounted on NASA's Infrared Telescope Facility (IRTF). Our goal is to study the thermal structure of Saturn's equatorial oscillation in 2015 and to search for the signature of thermal waves.

1. Introduction

In planetary middle atmospheres, waves play a critical role in the transport of momentum and energy. On Earth, interactions between vertically propagating waves and the mean zonal flow at the equator lead to a well-known dynamical phenomenon referred to as the Quasi-Biennial Oscillation (QBO) [2]. The QBO is characterized by an oscillation of the mean zonal wind and temperature of the equatorial stratosphere with a period of 22-34 months. At a given time, the vertical atmospheric profile shows a pattern of local minima and maxima of temperature alternating with height, as well as eastward and westward winds alternating with height. This pattern then propagates downwards over time.

An analoguous oscillation has recently been observed in Saturn's equatorial stratosphere [3, 4, 5], suggesting that equatorial oscillations are a common feature in planetary stratospheres. Ground-based observations have estimated the period of Saturn's oscillation to be 15 Earth years [3], hence half a Saturn year. However, the thermal structure of Saturn's stratosphere in 1980, derived from a re-analysis of Voyager observations, is inconsistent with a 15-year period for the oscillation [6]. In addition, the downward propagation of the oscillation may have been disturbed by the 2010 great storm.

Further observations of Saturn's vertical and meridional temperature gradients are thus needed to better characterize Saturn's equatorial oscillation and its period. In addition, observations resolving the longitudinal temperature field could reveal atmospheric waves, which properties (their horizontal and vertical wavelengths, phase velocities) are poorly documented. A better knowledge of the waves properties will help evaluate their role on the forcing of Saturn's oscillation, which mechanism is still poorly known.

2. Data analysis

Saturn was observed in the beginning of April, 2015 in two spectral regions and observing modes:

- High resolution (R$\sim$ 75,000) observations were performed in the methane ν_4 emission band (1245–1250 cm^{-1}) in nodding mode, with the TEXES slit oriented North/South and set at the central meridien of the planet. The longitudinal coverage was achieved by letting the planet rotate in the background.
- Medium resolution (R$\sim$15,000) scans of the planet were performed in the ethane band (815–822 cm^{-1}), achieving a much higher signal to noise ratio but with a less extended vertical sensitivity.

Temperature is first retrieved from the methane emission spectra, which probe the stratosphere between 10 and 0.01 mbar [7]. However, the signal to noise ratio is such that methane spectra acquired at different longitudes have to be co-added. Consequently, these observations are used to derive mean zonal temperature vertical profiles, at several latitudes.

On the other hand, temperature profiles can also be retrieved from the analysis of the ethane spectra, assuming a vertical profile for the ethane volume mixing ratio at a given latitude. Ethane abundance profiles are set to that retrieved from Cassini/CIRS observations, which revealed that ethane undergoes very little seasonal variations in the middle stratosphere [8].

Hence, these TEXES observations can be used to derive temperature variations with longitude and search for waves in Saturn's equatorial region.

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